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Reference research contract N00014-90-J-1930, Dr. Eileen E. Hofmann, principal investigator.

Enclosed is the final report entitled, "Physical-Biological Modeling Studies" for the period ended December 31, 1995.

If you have questions regarding the technical content of this report, please do not hesitate to call Dr. Hofmann at (804) 683-4945.

Sincerely,

Jacqueline K. Royster

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Grants & Contracts Administrator

/kjg

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FINAL REPORT

Physical-Biological Models Modeling Studies

Submitted by
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The primary accomplishment from the CTZ modeling work is the development and implementation of a combined biological, bio-optical and circulation model. This model is the first of this type to be applied to coastal ocean processes. The Lagrangian calculations showed that Taylor Caps are important in retaining plankton populations over seamounts. The combined biological, bio-optical and circulation models for the CTZ will likely serve as a prototype for future development of interdisciplinary models for coastal marine systems. The seamount Lagrangian particle simulations provided a better understanding of the relative contribution of circulation and biological processes to particle retention around these topographic features.

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1. Project Status

LONG-TERM GOALS: The overall goal of our research is to develop mathematical models that can be used to obtain a better understanding of the interactions between physical and biological processes in marine ecosystems.

SCIENTIFIC OBJECTIVE: The general objective of this research is to develop physical-biological models that can be used to understand and quantify the processes that contribute to the spatial and temporal development of nutrient and plankton distributions in the California Coastal Transition Zone (CTZ). An additional objective was to quantify general transport patterns and residence times for plankton populations around tall seamounts.

APPROACH: Two time- and space-dependent, physical-biological models have been developed for the CTZ. The first of these considers only time and vertical processes at specific locations in the CTZ. The model food web components include: silicate, nitrate, ammonium, two phytoplankton size fractions, copepods, doliolids, euphausiids and a detrital pool. The wavelength dependent attenuation of the subsurface irradiance field, due to sea water, phytoplankton pigment concentrations and dissolved organic matter, is incorporated as a depth-dependent energy flux which balances the phytoplankton energy uptake and the kinetic energy flux into the water. The second model considers the three-dimensional, time-dependent structure of plankton populations in the CTZ. A three-dimensional primitive equation model, developed to simulate the circulation features (filaments) observed in the CTZ, is used to advect the food web constituents of the bio-optical model. The circulation portion of the CTZ models was also used for Lagrangian particle tracking studies in order to determine general transport patterns and residence times in the CTZ.

Transport patterns and residence times around tall seamounts were investigated using circulation distributions obtained from a version of SPEM (Semi-Spectral Primitive Equation Model) that had been configured for flow over a tall Gaussian seamount.

Numerous particles were released in the simulated flow fields at several depths upstream and over the seamount. The particle trajectories were then analyzed to obtain transport directions and transit times. Some of the particles were given a behavior in order to simulate the effect of different migration strategies on particle retention around seamounts.

TASKS COMPLETED: The one and three-dimensional combined biological, bio-optical and circulation models have been developed and implemented for the CTZ. The Lagrangian particle tracing experiments for the seamount simulations have been completed and the results analyzed. Also, this project supported one Ph.D. student and one M.S. student, both of whom successfully completed all requirements for their degrees in Oceanography at Old Dominion University.

SCIENTIFIC RESULTS: The primary accomplishment from the CTZ modeling work is the development and implementation of a combined biological, bio-optical and circulation model. This model is the first of this type to be applied to coastal ocean processes. The Lagrangian calculations showed that Taylor Caps are important in retaining plankton populations over seamounts.

SIGNIFICANCE: The combined biological, bio-optical and circulation models for the CTZ will likely serve as a prototype for future development of interdisciplinary models for coastal marine systems. The seamount Lagrangian particle simulations provided a better understanding of the relative contribution of circulation and biological processes to particle retention around these topographic features.

2. Students Supported

This project provided support for one Ph.D. graduate student, Mr. John Moisan, and one M.S. student, Ms. Dorlisa Hommel. Moisan successfully completed the requirements for his Ph.D. degree in May 1993. He is now a research scientist at Scripps Institute of Oceanography. Ms. Hommel completed the requirements for her degree in December 1992. She is now employed at the Naval Research Laboratory in Stennis, MS.

3. Publication Citations

A. Published Abstracts

Haidvogel, D.B., J.R. Moisan and E.E. Hofmann, Simulated Lagrangian Drifter Experiments in the California Coastal Transition Zone Using a 3-D Coupled Physical-Biological Model, *EOS*, 72(51), 46-47. 1991.

Hofmann, E.E., K.S. Hedström, J.R. Moisan, D.B. Haidvogel, and D.L. Mackas, Use of Simulated Drifter Tracks to Investigate General Transport Patterns and Residence Times in the Coastal Transition Zone, *EOS*, 71(43), 1360-1361, 1990.

Hommel, D.L., Simulated Plankton Residence Times Over a Tall Seamount, *EOS*, 72(51), 60, 1991.

Hommel, D.L., Plankton Transport Patterns and Residence Times Around Tall Seamounts: Simulation Results, *EOS*, 73(43), 320, 1992.

Moisan, J.R., A Three-Dimensional Time-Dependent Physical-Biological Model of Nutrient and Plankton Processes in the Coastal Transition Zone, *EOS*, 71(43), 1361, 1990.

Moisan, J.R., A Model of Nutrient and Plankton Processes in the Coastal Transition Zone, *EOS*, 71(2), 145, 1990.

Moisan, J.R., Using a 3-D Physical, Bio-Optical Model to Investigate New Production and Cross-Shelf Carbon Transport in the California Coastal Transition Zone, *EOS*, 72(51), 61, 1991.

Moisan, J.R. and E.E. Hofmann, Circulation and Bio-optical Models: An Example from the Coastal Transition Zone, *EOS*, 72(44), 252, 1991.

Moisan, J.R. and E.E. Hofmann, Modeling the Nutrient and Plankton Processes in the California Coastal Transition Zone, *EOS*, 73(43), 303, 1992.

B. Reviewed Publications

Hofmann, E.E., 1991, How Do We Generalize Coastal Models to Global Scale?, In: *Ocean Margin Processes in Global Change*, Eds. R.F.C. Mantoura, J.-M. Martin and R. Wollast, Dahlem Konferenzen, Chichester, John Wiley & Sons, Ltd., 401-417.

Hofmann, E.E., 1993, Coupling of Circulation and Marine Ecosystem Models, In: *Patch Dynamics*, eds., S.A. Levin, T.M. Powell and J.H. Steele, Lecture Notes in Biomathematics, Vol. 96, Springer-Verlag, 136-161.

Hofmann, E.E., Structured Population Models for Marine Systems, Chapter 13 in, *Structured Population Models in Marine, Freshwater, and Terrestrial Systems*, S. D. Tuljapurkar and H. Caswell, eds., Chapman & Hall, New York, in press.

Hofmann, E.E., K.S. Hedström, J.R. Moisan, D.B. Haidvogel, and D.L. Mackas, 1991, Use of Simulated Drifter Tracks to Investigate General Transport Patterns and Residence Times in the Coastal Transition Zone, *Journal of Geophysical Research*, 96, 15,041-15,052.

Hofmann, E.E. and C.M. Lascara, A Review of Predictive Modeling for Coastal Marine Ecosystems, in: *Coastal Prediction*, C.N.K. Mooers, ed., CRC Press, in press.

Hommel, D.L., Plankton Transport and Residence Times Around Tall Seamounts: Simulation Results, M.S. Thesis, Old Dominion University, pp. 77, December 1992.

Moisan, J.R., Modeling Nutrient and Plankton Processes in the California Coastal Transition Zone, Ph.D. Dissertation, Old Dominion University, 214 pp, May 1993.

Moisan, J.R. and E.E. Hofmann, Modeling Nutrient and Plankton Processes in the California Coastal Transition Zone. 1. A Time- and Depth-Dependent Model, *Journal of Geophysical Research*, in press.

Moisan, J.R., E.E. Hofmann and D.B. Haidvogel, Modeling Nutrient and Plankton Processes in the California Coastal Transition Zone. 2. A Three-Dimensional Physical-Bio-Optical Model, *Journal of Geophysical Research*, in press.

Moisan, J.R., E.E. Hofmann and D.B. Haidvogel, Modeling Nutrient and Plankton Processes in the California Coastal Transition Zone. 3. Lagrangian Calculations, *Journal of Geophysical Research*, in press.

C. Presentations

Haidvogel, D.B., J.R. Moisan and E.E. Hofmann, Simulated Lagrangian Drifter Experiments in the California Coastal Transition Zone Using a 3-D Coupled Physical-Biological Model, Poster presentation at the 1992 Ocean Sciences Meeting, New Orleans, LA.

Hofmann, E.E., Circulation and Bio-Optics Models, Oral presentation at the JGOFS Modelling Workshop on Processes Determining Primary Production in the Southern Ocean, British Antarctic Survey, Cambridge, England, 16-19 October, 1991.

Hofmann, E.E., Aspects of Physical-Biological Models for Secondary Production Studies, Invited presentation at ICES Symposium on Zooplankton Production, Plymouth, England, 15-19 August, 1994.

Hofmann, E.E., K.S. Hedström, J.R. Moisan, D.B. Haidvogel, and D.L. Mackas, Use of Simulated Drifter Tracks to Investigate General Transport Patterns and Residence Times in the Coastal Transition Zone, Oral presentation at 1990 Fall AGU Meeting, San Francisco, CA.

Hommel, D.L,, Simulated Plankton Residence Times Over a Tall Seamount, Oral presentation at the 1992 Ocean Sciences Meeting, New Orleans, LA.

Hommel, D.L., Plankton Transport Patterns and Residence Times Around Tall Seamounts: Simulation Results, Poster presentation at the 1992 Fall AGU Meeting.

Moisan, J.R., A Model of Nutrient and Plankton Processes in the Coastal Transition Zone, Poster presentation at 1990 Ocean Sciences Meeting, New Orleans, LA.

Moisan, J.R., A Three-Dimensional Time-Dependent Physical-Biological Model of Nutrient and Plankton Processes in the Coastal Transition Zone, Oral presentation at the 1990 Fall AGU Meeting, San Francisco, CA.

Moisan, J.R., Using a 3-D Physical, Bio-Optical Model to Investigate New Production and Cross-Shelf Carbon Transport in the California Coastal Transition Zone, Oral presentation at the 1992 Ocean Sciences Meeting, New Orleans, LA.

Moisan, J.R. and E.E. Hofmann, Circulation and Bio-optical Models: An Example from the Coastal Transition Zone, Oral presentation at the 1991 Fall AGU Meeting.

Moisan, J.R., A Coupled 1-D Mixed Layer Bio-Optical Model, Oral presentation at the 1992 ASLO Meeting, Santa Fe, New Mexico, 10-14 February 1992.

Moisan, J.R. and E.E. Hofmann, Modeling the Nutrient and Plankton Processes in the California Coastal Transition Zone, Oral presentation at the 1992 Fall AGU Meeting.

Moisan, J.R., A Vertical, Time-Dependent Bio-Optical Model, Poster presentation at the Brookhaven Symposia in Biology No. 37 on Primary Productivity and Biogeochemical Cycles in the Sea, Brookhaven National Laboratory, 2-6 June 1991

Moisan, J.R., A Coupled 1-D Mixed Layer Bio-Optical Model, Oral presentation at the 1992 ASLO Meeting, Santa Fe, New Mexico, 10-14 February 1992.